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(54) Cavity-coupled microwave power device

(57) In a microwave combining device active elements 10 are coupled to a common output by means of a dielectric cavity 40 on the periphery of which are arranged line portions 30 parallel to the axis of the cavity and each connected to a respective active element, the line portions 30 being arranged on a surface of a support 11 surrounding the dielectric cavity, and the relative position of the dielectric cavity and the support being adjustable in a direction parallel to the axis of the cavity. This enables the coupling between the dielectric cavity and the active elements and between the dielectric cavity and the load (20, Fig. 5) to be adjusted. The active elements may be Grumm or Avalanche diodes or may be transistors. In one embodiment FET's (90, Figs. 9 and 10) are employed in a further embodiment transistors (110, Figs. 11 and 12) are employed. The combining device may be used as an oscillator or amplifier.

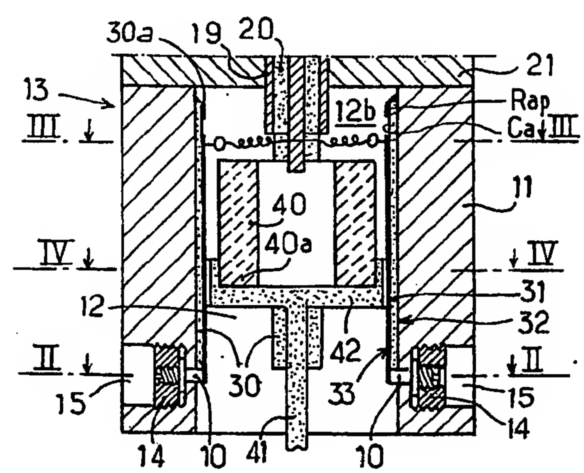

FIG.1

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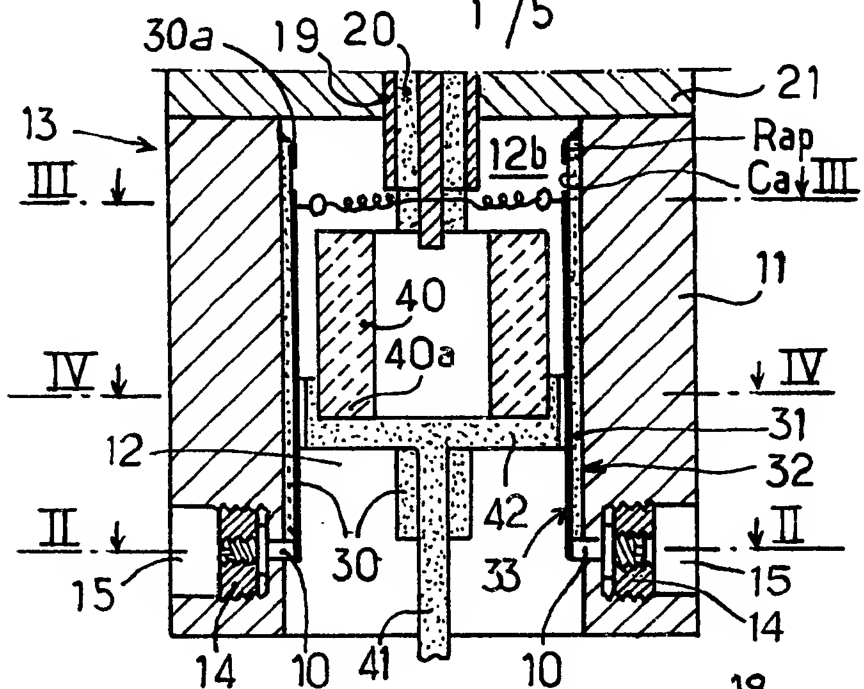


FIG.1

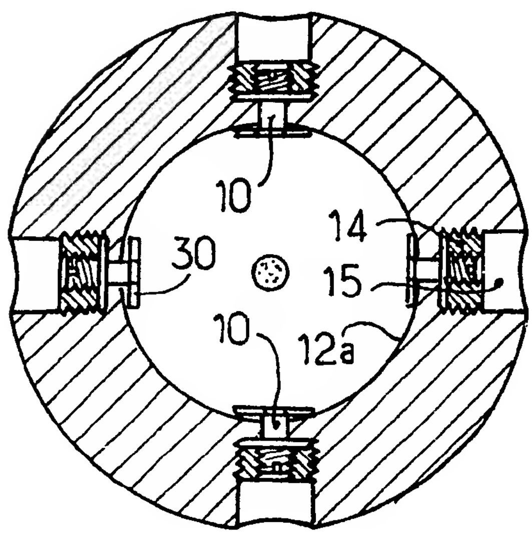


FIG.2

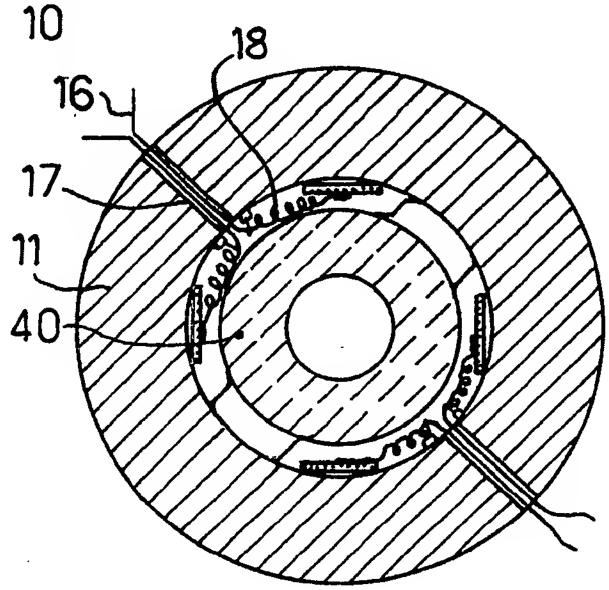


FIG.3

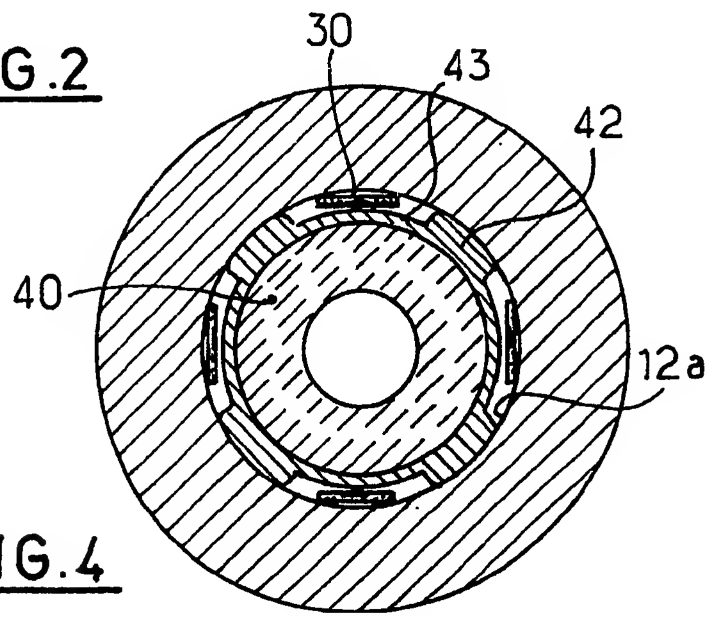


FIG.4

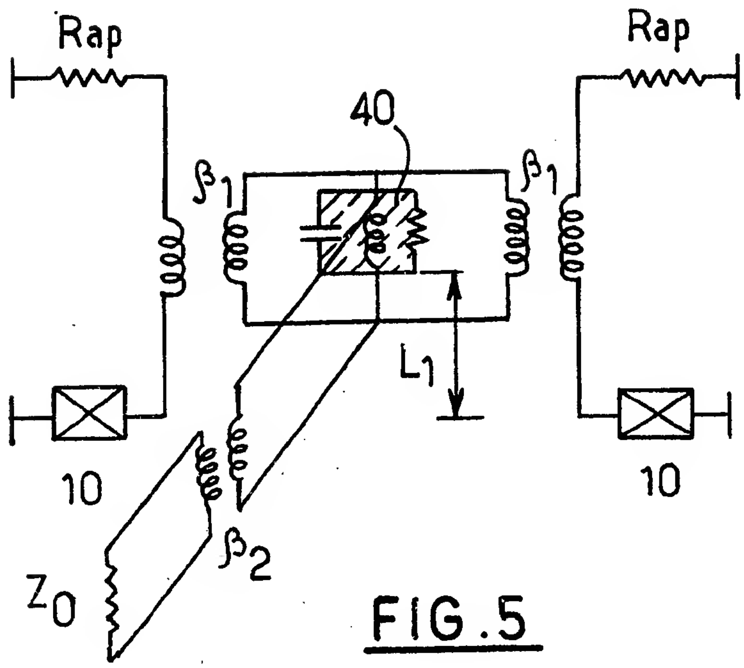

Rap
Rap
40
β_1
β_1
L_1
10
10
β_2
Z_0

FIG.5

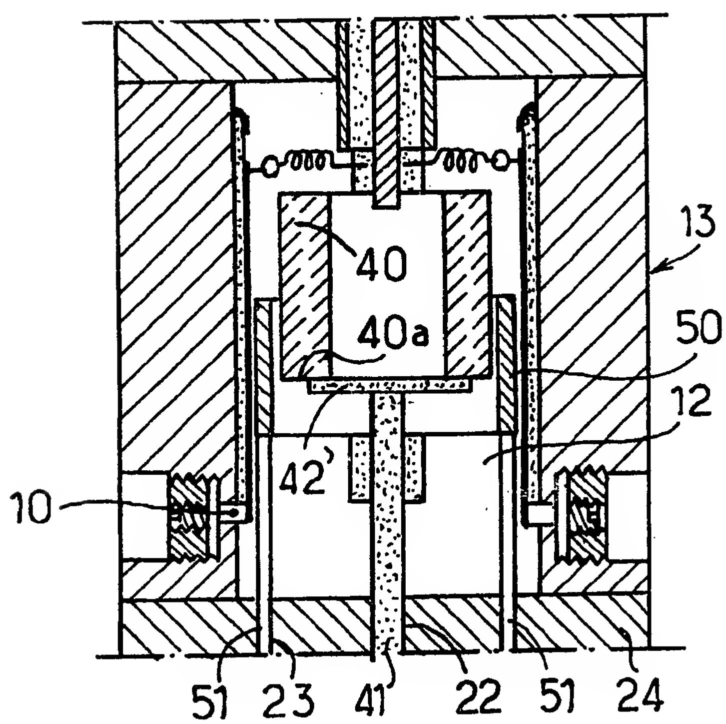

13
40
40a
50
12
42'
10
51
23
41
22
51
24

FIG.6

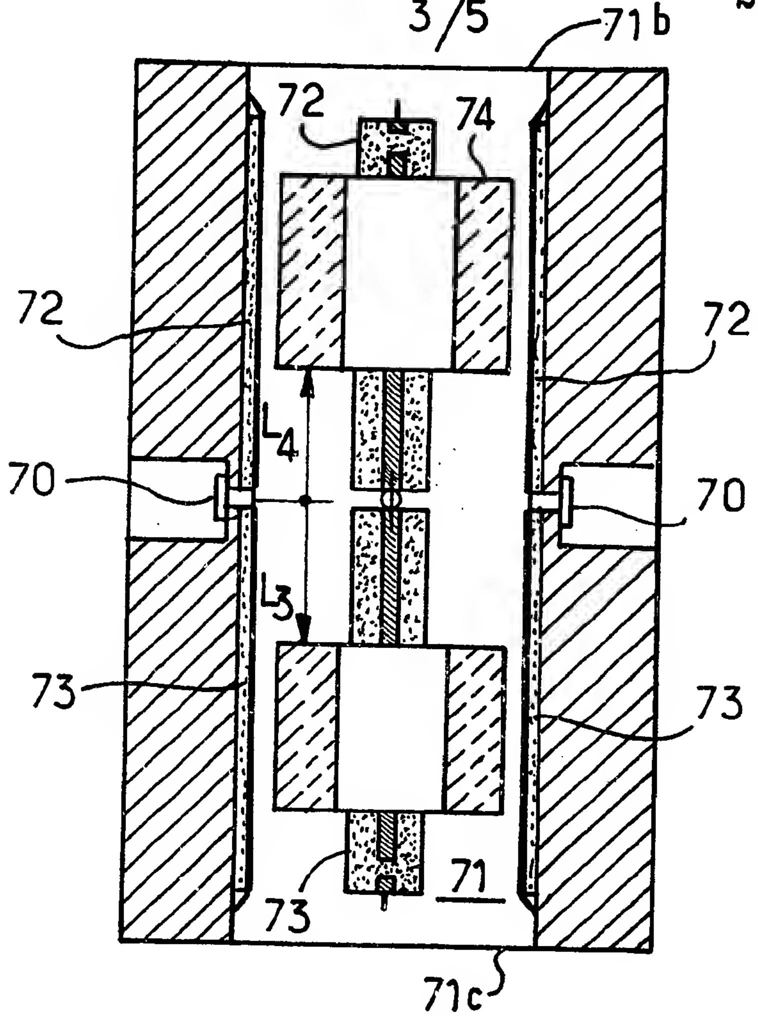

71b
72
74
72
72
L4
70
70
L3
73
73
73
71
71c

FIG.7

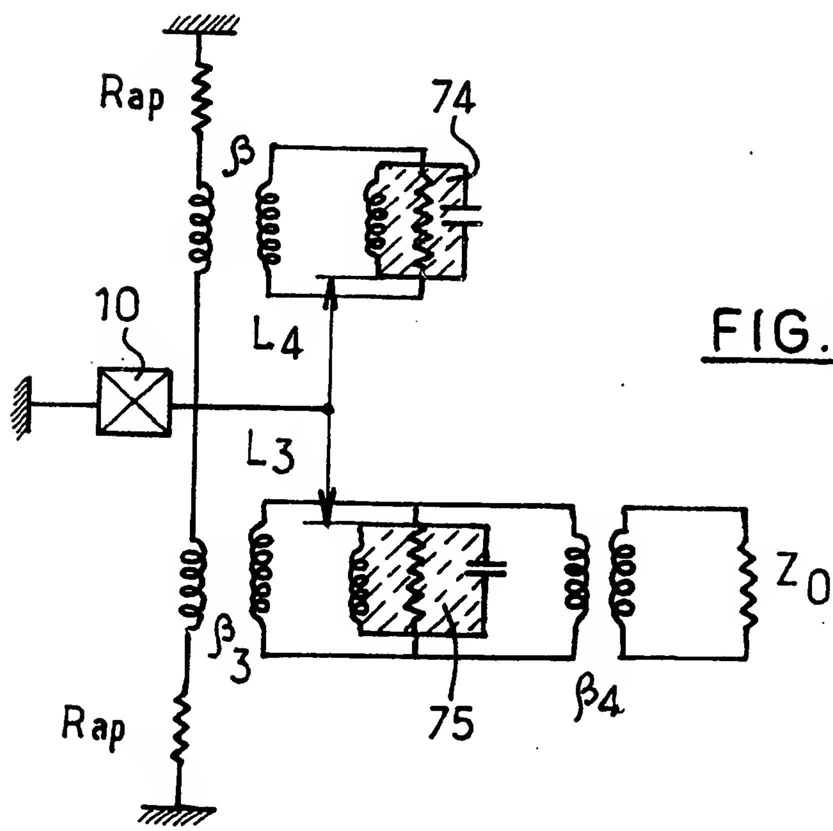

Rap
β
74
10
L4
L3
Z0
β3
β4
75
Rap

FIG.8

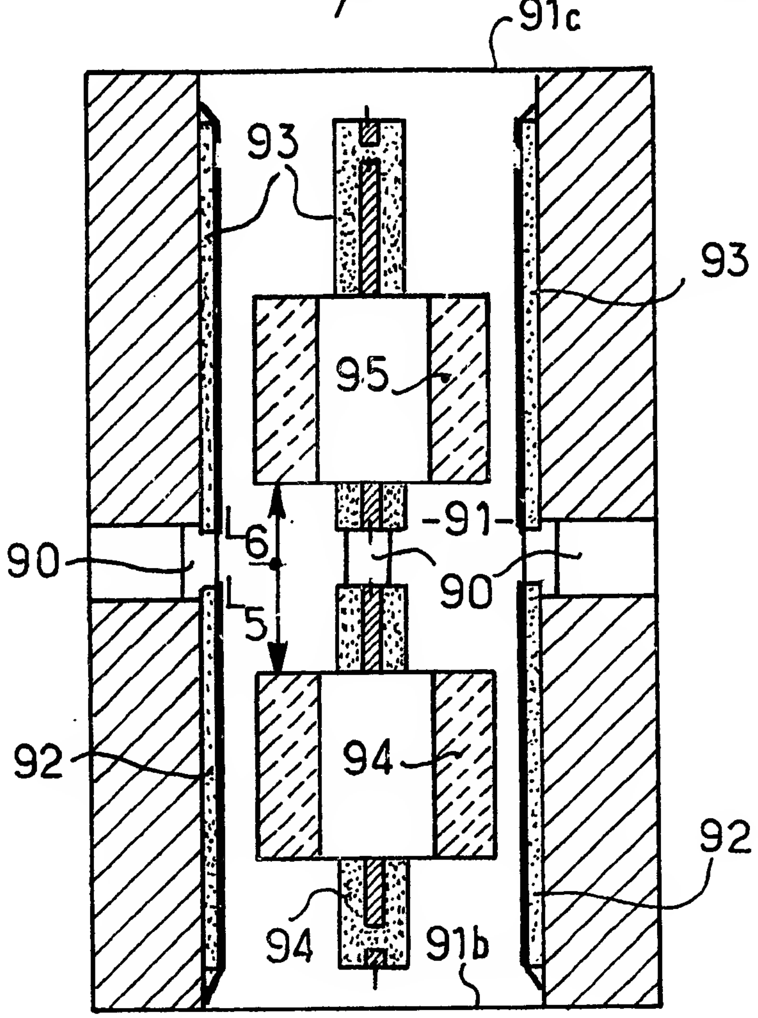

91c
93
93
95
91
90
L6
L5
90
92
94
92
94
91b

FIG.9

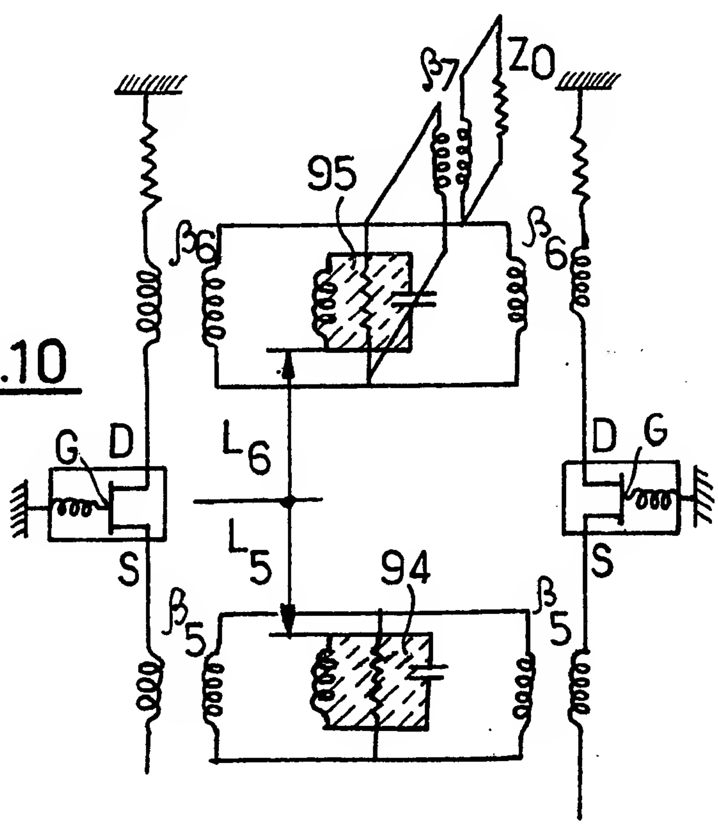

β7
ZO
95
β6
β6
G
D
L6
D
G
L5
S
S
94
β5
β5

FIG.10

FIG.11

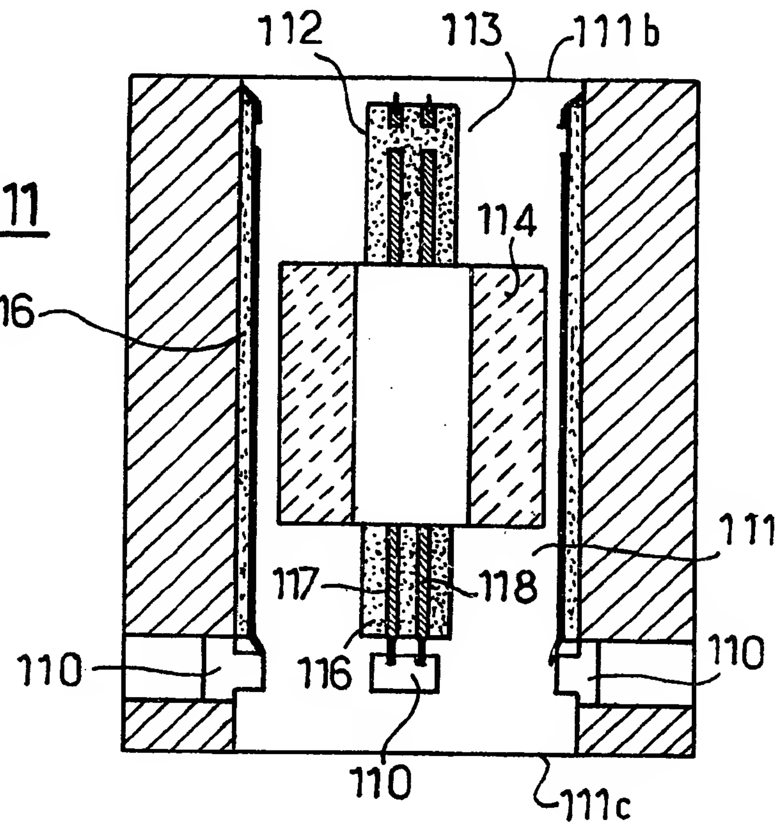
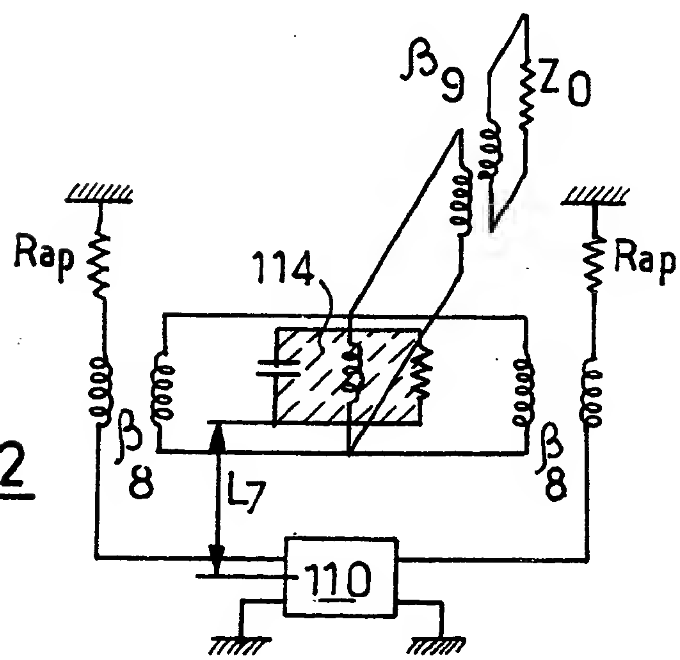

112
113
111b
114
116
111
117
118
110
116
110
110
110
111c

FIG.12


β9
Z0
Rap
Rap
114
β8
β8
L7
110

SPECIFICATION

Cavity-coupled microwave power device

The present invention relates to a microwave power combining device of the type incorporating a plurality of active elements coupled to a common output by means of a cavity. The invention is more particularly applicable to oscillators or power amplifiers operating in the microwave range.

In known devices of this type the active elements are usually coupled by means of a metallic cavity. A known example has a metallic cavity on the inner periphery of which are arranged coaxial line portions which each extend parallel to the axis of the cavity between an active element and an absorbing load. Such a combiner is described, for example, in the document FR-A-2,292,370.

With these known devices, it is usually difficult or even impossible to adjust the distance between the active elements and the cavity in a fixed manner. Furthermore, the use of these devices is limited to the coupling of active dipoles, such as, for example, Gunn diodes or avalanche diodes.

According to the present invention a microwave power combining device having a plurality of active elements coupled to a common output by means of a dielectric cavity on the periphery of which are arranged line portions parallel to the axis of the cavity and each connected to a respective one of the active elements, has line portions arranged on the surface of a support surrounding the dielectric cavity, the relative positions of the dielectric cavity and the support being adjustably movable parallel to the axis of the cavity.

The present invention is thus able to provide simple, continuous fine adjustment of the distances between the active elements and the cavity, the use with which is not limited to dipoles, but also extends to quadripoles, such as bipolar or field effect transistors.

Various types of lines can be used to produce the line portions connected to the active elements, for example lines of the micro-ribbon, coplanar, fin-like, three-layer or coaxial type. However, it is preferable by far to use lines of the "plane" type, that is to say micro-ribbon, coplanar or fin-line, to prevent discontinuities formed by the openings which have to be made in lines of the three-layer or coaxial type for coupling to the cavity.

In one particular embodiment the active elements are of the quadripole type, each with a first terminal connected to a first line portion and a second terminal connected to a second line portion, the active elements being coupled to their first terminals and to their second terminals by means of at least one dielectric cavity. These couplings can be made by means of two separate dielectric cavities, preferably with independent means for adjusting the distances between each dielectric cavity and the support carrying the corresponding line portions.

Preferably, there is an element for adjusting the coupling between the active elements and the dielectric cavity, this adjusting element being made, for example, in the form of a ring which has the same axis as the cavity and is located between the latter and the line portions and the relative position of which in relation to the cavity or to the active elements is adjustable in a direction parallel to the axis of the cavity.

In devices according to the invention, it is possible to use cavities of cylindrical, parallelepipedic or even spherical shape resonant in a TM or even a TE mode or even a hybrid mode (EH). Moreover, the coupling between the dielectric cavity and the line portions connected to the active elements can be of the magnetic or electrical type.

Other particular features or advantages of the device according to the invention will emerge from a reading of the following description with reference to the attached drawings in which:—

Figure 1 is a diagrammatic view in axial section, of a first embodiment for coupling dipoles;

Figures 2 to 4 are sectional views along the line II—II, III—III and IV—IV in Figure 1;

Figure 5 is an equivalent diagram of the device in Figure 1;

Figure 6 is a diagrammatic view, in axial section, of an alternative embodiment of the combining device in Figure 1;

Figure 7 is a diagrammatic view, in axial section, of a second embodiment of a combining device according to the invention for coupling dipoles with parallel tuning;

Figure 8 is an equivalent diagram of the device in Figure 7;

Figure 9 is a diagrammatic view, in axial section, of a third embodiment of a combining device according to the invention for coupling quadripoles (transistors);

Figure 10 is an equivalent diagram of the device in Figure 9;

Figure 11 is a diagrammatic view, in axial section of a fourth embodiment of a combining device according to the invention for coupling quadripoles, and

Figure 12 is an equivalent diagram of the device in Figure 11.

The following description explains in a non-limiting way the case where there is coupling of the magnetic type between active elements and a cavity resonant in the TM mode.

Figures 1 to 4 illustrate a combining device grouping active elements 10 by means of a dielectric cavity. The active elements 10 are dipoles (or quadripoles connected as dipoles) which have in a conventional way a negative resistance under suitable bias conditions, for example Gunn diodes or avalanche diodes. The elements 10 are arranged in a ring at regular intervals on the inner surface 12*a* of a cylindrical receptacle 12 formed in a tubular part 11 of a metal support 13. Each active element is carried by a component 14 screwed into a radial orifice

15 formed in the tubular part 12 (Figure 2).

A line portion 30 of the micro-ribbon type welded to the surface 12*a* is connected to each active element 10. The line portion 30 extends parallel to the axis of the receptacle 12 and comprises a strip-shaped ceramic substrate 31 which has on one face a metallisation 32 forming an earth and welded to the surface 12*a* and, on the other face turned towards the centre of the receptacle 12, a metallisation 33. As can be seen in Figure 1, the elements 10 are arranged in the vicinity of one end of the receptacle 12, and the line portions 30 extend almost over the entire length of this receptacle. At its end 30*a* opposite that connected to an active element 10, each line portion 30 is connected to earth by means of a decoupling capacitor Ca, formed by an interruption in the metallisation 33, and an anti-interference resistor Rap. Furthermore, for biassing each active element, the associated line portion 30 is connected to the outside of the receptacle 12 by means of a connection comprising a conductor 16 passing through an orifice 17 in the tubular part 11 and connected to the line portion 30 in the vicinity of its end 30*a* by means of a choke coil 18 (Figure 3). A decoupling capacitor can be connected between the conductor 16 and the earth formed by the inner surface of the receptacle 12.

The active elements 10 are coupled to one another by means of the dielectric cavity 40 of cylindrical or, more precisely, tubular shape and with the same axis as the receptacle 12. The cavity 40 is connected at one end 40*a* to an axial rod 41 made of insulating material, for example glass, by means of an insulating connecting piece 42 in which the end part 40*a* of the cavity 40 is set. The piece 42 has an outside diameter equal to the inside diameter of the receptacle 12 and has on its periphery notches 43 so as not to interfere with the line portions 30 and the active elements 10 (Figure 4). The rod 41 is extended to the outside of the support 12 so as to allow the cavity 40 to move in axial translation in the receptacle 12 by means of the guidance of the connecting piece 42 along the surface 12*a*.

The connection to a consumer load is made by means of a line 20, for example of the coaxial type, the end of which penetrates axially into the receptacle 12 on the side 12*b* opposite that through which the rod 41 passes and in the vicinity of which the active elements 10 are located. The line 20 is guided, for example, through a hole 19 formed in a part 21 of the support 13 closing the side 12*b* of the receptacle 12.

Figure 5 shows an equivalent diagram of the device (only two active elements 10 are shown so as not to complicate the drawing). β_1 and β_2 denote the coupling coefficients between the dielectric cavity 40 and the active elements 10 and between the dielectric cavity and the consumer load Z_0. By acting on the rod 41 it is possible to adjust precisely and continuously the distance L_1 between the active elements 10 and the cavity 40. Of course, the receptacle 12 must have a specific resonant frequency outside the frequency range in which the device operates. As an indication, a device such as that illustrated in Figure 1 was used to couple four Gunn diodes. The line portions 30 comprised an alumina substrate 31 with a thickness of 0.4 mm and a width of 2 mm and with an engraved line 33 with a width of 0.4 mm. By means of a dielectric cavity with an inside diameter of 2 mm, an outside diameter of 15 mm and a length of 4 mm arranged in a receptacle 12 with a diameter of 17 mm, it was possible to obtain a combining efficiency equal to 70% for an output power of 1 W at 11 GHz.

An alternative embodiment of the device in Figure 1 is illustrated in Figure 6. The device shown in Figure 6 differs essentially from that of Figure 1 in that a dielectric ring 50 is located in the receptacle 12 between the cavity 40 and the line portions 30. Consequently, the connection between the rod 41 and the cavity 40 is made by a component 42′ simply produced, for example, in the form of an insulating disc bonded to the end 40*a* of the cavity. Two insulating rods 51 made, for example, of glass are fastened to the end edge of the ring 50 facing the side 12*b* of the receptacle. The rods 41, 51 are guided in holes 22, 23 formed in a part 24 of the support 13 and project outside this support. By acting on the rods 51, it is possible to move the ring 50 in axial translation in relation to the active elements 10 and the cavity 40. In addition to adjustment of the distance between the active elements and the dielectric cavity, it is therefore possible by means of the ring 50 to carry out fine and continuous adjustment of the coupling between the active elements and the dielectric cavity.

Various other embodiments of a combining device according to the invention will now be described with reference to Figures 7 to 12. For the sake of simplicity, the means of assembly and biassing of the active elements, the arrangement of the dielectric cavities and the common output line, and the possible use of a coupling adjustment ring are not illustrated. They can be produced as described above with reference to Figures 1 to 6.

Figure 7 shows dipoles 70 arranged at regular intervals and in a ring on the periphery of the inner surface of a cylindrical receptacle 71. The dipoles 70 are located substantially in the central part of the receptacle 71 and are each connected to two line portions 72, 73 of the micro-ribbon type welded to the inner surface of the receptacle 71 and parallel to the axis of the latter. The line portion 72 extends from the active element towards one end 71*b* of the receptacle, whilst the line portion 73 extends from the active element towards the other end 71*c* of the receptacle 71. A first dielectric cavity 74 is arranged in the receptacle 71 opposite the line portions 72, and a dielectric cavity 75 is arranged in the receptacle 71 opposite the line portions 73. This arrangement makes it possible by means of the dielectric cavity 75 to couple parallel-tuned

dipoles 70 to a consumer load by means of the dielectric cavity 74. The relative position of the cavities 74, 75 in relation to the active elements 70 are adjustable independently of one another as a result of axial translation.

The equivalent diagram of the device in Figure 7 can be seen in Figure 8. Only one active element is shown for the sake of clarity in the drawing. B denotes the coupling coefficient between the active elements and the dielectric cavity 74. B_3 and B_4 denote the coupling coefficients between the active elements and the dielectric cavity 75 and between this and the consumer load Z_0. The distances L_3 and L_4 between the active elements and the cavity 75 and between the active elements and the cavity 74 can be adjusted finely and continuously.

Figure 9 illustrates a power combining device with the coupling of active elements formed by quadripoles, for example field-effect transistors 90. The transistors 90 are arranged at regular intervals and in a ring on the periphery of the inner surface of a cylindrical receptacle 91. Each transistor 90 has one terminal, for example the source, connected to a line portion 92 of the micro-ribbon type and another terminal, for example the drain, connected to another line portion 93 of the micro-ribbon type. The line portions 92 and 93 are welded to the inner surface of the receptacle 91 and are parallel to the axis of the latter. The line portion 92 extends from the transistor 90 towards one end 91*b* of the receptacle 91, whilst the line portion 93 extends from the transistor 90 towards the other end 91*c* of the receptacle 91. A dielectric cavity 94 is arranged in the receptacle 91 opposite the line portions 92, whilst a second dielectric cavity 95 is arranged in the receptacle 91 opposite the line portions 93. This produces, by means of the cavity 94, collective tuning of the translstors 90 via one of their terminals and coupling of these transistors to a consumer load via one of their terminals by means of the cavity 95. The axial positions of the cavities 94 and 95 are adjustable independently of one another.

Figure 10 shows an equivalent diagram of the device in Figure 9, only two transistors 90 being illustrated. β_5 denotes the coupling coefficient between the active elements and the dielectric cavity 94. β_6 and β_7 denote the coupling coefficients between the active elements and the cavity 95 and between this and the consumer load Z_0. The field-effect transistors 90 are tuned via the source S, coupled via the drain D and connected to a common grid G. The movement of the dielectric cavities 94 and 95 in axial translation makes it possible to adjust the distances L_5 and L_6 between the active elements and the cavity 94 and between the active elements and the cavity 95.

Another method of collective coupling of quadripoles 110 is shown in Figure 11. The quadripoles 110, for example transistors, are arranged at regular intervals and in a ring on the periphery of the inner surface of a cylindrical receptacle 111 in the vicinity of one end 111*c* of the latter. Each transistor 110 has a first terminal connected to a line portion 112 of the micro-ribbon type and a second terminal connected to a line portion 113 of the micro-ribbon type, the various lines 112 and 113 extending parallel to the axis of the receptacle 111 in the direction of the other end 111*b* of the latter, and being welded to the inner surface of the receptacle. A dielectric cavity 114 is arranged in the receptacle 111 and effects collective coupling of the transistors 110 both via their first terminals and via their second terminals. It will be noted that the line portions 112 and 113 connected to one and the same transistor 110 can have a common substrate 116 carrying two metallised lines 117, 118 connected respectively to the first and second terminals of the transistor.

Figure 12 shows an equivalent diagram of the device in Figure 11. β_8 and β_9 denote the coupling coefficients between the active elements and the cavity 114 and between this and the consumer load Z_0. The cavity 114 can move in axial translation in relation to the receptacle 111 so as to adjust the distance L_7 between it and the active elements 110.

The embodiments described above were all concerned with the case where the line portions connected to the active elements are of the micro-ribbon type. As already mentioned, these line portions could also be of another plane type known per se, for example of the coplanar type or of the fin-line type, that is to say with two metallisations formed on one and the same face of a substrate, the other face of which is metallised if appropriate. As regards a coplanar line, one of the two metallisations formed on one and the same face of the substrate constitutes the earth and is separated from the other metallisation by a gap of constant width. As regards a finline, transmission along the line takes place by exchange between the two metallisations. The use of lines of the three-layer or coaxial type, although being less advantageous, is not excluded.

Claims

1. A microwave power combining device having a plurality of active elements coupled to a common output by means of a dielectric cavity on the periphery of which are arranged line portions parallel to the axis of the cavity and each connected to a respective one of the active elements, the line portions being arranged on the surface of a support surrounding the dielectric cavity, and the relative positions of the dielectric cavity and the support being adjustably movable parallel to the axis of the cavity.

2. A device according to claim 1, in which the line portions are of the plane type.

3. A device according to claim 1 or claim 2, which incorporates an element for adjusting the coupling between the active elements and the dielectric cavity.

4. A device according to any of claims 1 to 3, in which the adjusting element comprises a ring

coaxially disposed relative to said cavity and located between the cavity and the line portions, and means for adjusting the relative position of the element, in relation to the cavity or to the active elements, in translation parallel to axis of the cavity.

5. A device according to any of claims 1 to 4, in which the active elements are of the quadripole type each element having a first terminal connected to a first line portion and a second terminal connected to a second line portion, the active elements being coupled to their first terminals and to their second terminals by at least one dielectric cavity.

6. A device according to claim 5, in which the elements are coupled to by means of two separate dielectric cavities, and means for adjusting the distances between the cavities and the active elements independently of one another.

7. A device according to claim 5, in which the elements are coupled to terminals by means of a single dielectric cavity.

8. A device according to any of claims 1 to 4, in which the active elements comprises dipoles, each dipole connected to first and second line portions extending in opposite directions from the dipole, a first dielectric cavity being disposed opposite the first line portions to effect collective tuning coupling of the dipoles, and a second dielectric cavity being disposed opposite the second line portions to effect collective coupling of the dipoles to a load.

9. A device according to any of claims 1 to 8, including an insulating rod, the dielectric cavity being fixed to said rod making it possible to move the cavity in relation to the active elements.

10. A device according to any of claims 1 to 9, including a receptacle having an inner surface and being formed in a metal support and having a specific resonant frequency outside the operating frequency range of the device, the line portions being welded to the inner surface.

11. A microwave power combining device substantlally as described with reference to any of the examples shown in the accompanying drawings.

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